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Research Memorandum 72-4

INTELLIGENCE INFORMATION FROM TOTAL OPTICAL COLOR IMAGERY

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INTELLIGENCE INFORMATION FROM TOTAL OPTICAL COLOR IMAGERY

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INTELLIGENCE INFORMATION FROM TOTAL OPTICAL COLOR IMAGERY

BACKGROUND

The present publication describes an evaluation of total optical color imagery as a source of intelligence information. The U. S. Army was invited to participate in the evaluation program. The test conducted was an empirical assessment of Total Optical Color (TOC) imagery as a source of raw intelligence data. This imagery consisted of aerial surveillance photographs acquired over the UNDERBRUSH test range at Eglin Air Force Base, Florida.

The test plan, prepared by the Joint Test Team composed of members from Rome Air Development Center, USMC Development and Education Command, and the Naval Reconnaissance and Technical Support Center, is presented in part in the following three paragraphs:

ARPA (Advanced Research Projects Agency) has been pursuing the color modulation system developed by Technical Operations, Inc.[1] for a number of years. This program has involved two major aspects: (a) modified 35mm cameras which use standard black and white films, and (b) striped film which may be used in unmodified cameras. The Technical Operations, Inc.[1] system provides color imagery from black and white film, thereby eliminating sophisticated processing equipment, precision techniques, excessive logistics, and high costs associated with standard color film.

Rome Air Development Center, Griffiss AFB, NY has the engineering responsibility for the film striping portion of the TOC program which is being funded through FY71 by ARPA. ARPA has procured and distributed to the military services several TOC-modified 35mm cameras and associated viewers. However, to date, only limited evaluations of this system have been conducted.

At a joint meeting of representatives from the Air Force, Navy, and Marine Corps held in January 1970, it was agreed that a joint qualitative evaluation of the 35mm TOC system should be conducted. Such an evaluation would be of value to all participating services in programming and planning future application of the TOC system.

PURPOSE OF THE RESEARCH

The TOC 35mm system was compared to a system providing conventional color imagery and to a system providing monochromatic imagery. The evaluation included a subjective appraisal as well as an empirical assessment. The following specific objectives were established:

1/ Reference to the commercial firm and its product is in the interest of precise reporting and does not signify indorsement by BESRL or the Army.

1. To determine the total time required for the extraction of the required target information from the three kinds of experimental imagery.

2. To determine the accuracy and completeness with which image interpreters detected the required targets in the experimental imagery.

3. To determine the accuracy and completeness with which image interpreters identified the required targets in the experimental imagery.

4. To obtain, by means of a questionnaire, preference data from the experimental subjects regarding their relative likes and dislikes for the competing systems.

METHOD

EXPERIMENTAL MATERIALS

Imagery. The available imagery was in the format of 2 x 2 inch slides. The imagery had been acquired using two identical 35mm cameras one of which had been modified to record TOC 35mm exposures while the other recorded on conventional color film (Ektachrome)[2]. Since the imagery acquired by the TOC-modified camera was recorded on black-and-white film (Panatomic X)[2], three distinct modes of presenting each scene were possible. The TOC imagery could be presented as monochromatic imagery or in available color as reconstituted by the TOC viewer. Conventional color imagery was the third type.

The two identical cameras were mounted on the same camera bar and fitted with shutter controls that could be actuated simultaneously so that the same scene was recorded by both cameras. In this way, each scene photographed was recorded on conventional color film and on the black-and-white film for the TOC system.

Eighteen slides were selected from among available slides. The slides were selected to include a variety of target types and to make certain that in each case both the conventional color slide and the TOC slide were of acceptable photographic quality. The 18 slides were randomly broken down into three sets of six slides each, designated as Set A, Set B, and Set C. Pre-test materials consisted of other slides used to acquaint the subject with the task. Finally, four additional slides were selected for use in allowing the experimental subjects to manipulate the color controls on the TOC viewer prior to filling out the questionnaire.

Questionnaire. A simple one-page questionnaire was prepared in order to gather the subjective impressions of the experimental subjects concerning the usefulness of being able to vary the color balance of the display and the desirability of the binocular viewer as a viewing device. A copy of this questionnaire appears in Appendix B.

2/ Reference to the commercial firm and its product is in the interest of precise reporting and does not signify indorsement by BESRL or the Army.

Equipment. The TOC binocular viewer is described in literature prepared by Technical Operations, Inc. and is not described here. 3/ One additional piece of equipment was used--a timer to measure total elapsed time taken for analysis of each slide. This instrument was a three-digit counter pulsed once per second.

RESEARCH DESIGN

The 18 selected slides, assigned to three scene sets of six slides each, were presented to three groups of subjects with four image interpreters in each group. The scene set/presentation color combinations used were unique for each subject group. A Latin square design was used to vary systematically the order in which the scene set/presentation color combinations were administered to the three groups (Figure 1).

Presentation Color Mode

	Ekta-chrome	Black & White	TOC
Group I	Set A	Set C	Set B
Group II	Set C	Set B	Set A
Group III	Set B	Set A	Set C

Figure 1. Experimental Design for TOC Evaluation

SUBJECTS

The experimental subjects were all trained image interpreters. With one exception, they had received their formal training at the U. S. Army Intelligence School, then at Fort Holabird, Maryland. They had served in operational units prior to coming to BESRL where they were then working in their MOS specialty.

3/ Reference to the commercial firm and its product is in the interest of precise reporting and does not signify indorsement by BESRL or the Army.

VARIABLES

Independent Variables. The independent variables have been discussed in the preceding sections dealing with imagery characteristics and experimental design. Color mode under which the scenes were viewed was of primary interest. Three categories of this nominal variable were used: Ektachrome color, black and white, and Total Optical Color (TOC). 4/ Three sets of six scenes each and three groups of subjects were used to make it possible to present the experimental task to the subjects in counterbalanced arrangement.

Dependent Variables. The measures used to assess interpreter performance can be explained most readily by describing the raw scores obtained from each interpreter's responses and then presenting the formulas used to compute the derived indexes. Interpreter responses were scored to determine the following:

1. Number of correct target identifications
2. Number of incorrect target identifications (misidentifications)
3. Number of targets invented--non-targets named as targets
4. Number of targets omitted
5. Total time required for the completion of each slide

From these five basic scores the following indexes of performance were computed:

IDENTIFICATION ACCURACY = (1)/(1 + 2 + 3)

IDENTIFICATION COMPLETENESS = (1)/(1 + 2 + 4)

DETECTION ACCURACY = (1 + 2)/(1 + 2 + 3)

DETECTION COMPLETENESS = (1 + 2)/(1 + 2 + 4)

TOTAL TIME PER SLIDE

DATA COLLECTION

The experimental materials had to be presented using the binocular viewer developed for the purpose of re-capturing the color information encoded by the TOC system. 4/ Consequently, each subject was tested separately.

A preliminary session was conducted in which the viewing apparatus was adjusted to fit the individual characteristics of the subject--inter-

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pupilary distance, focus, and differential settings of the two eye-pieces to compensate for differences in visual acuity between the two eyes, for example. A target list on which the names of the required targets were listed was given the subject for study and reference use during the experiment. This list included objects which did not appear on the imagery as well as those that were imaged. A copy of the instructions and the target list appears in Appendix B.

The preliminary instructions included training the subject how to report the location of the objects he detected. Location was done in a rough manner. A slide was presented to the subject showing the visual field divided into four quadrants. These quadrants were numbered starting with 1 in the upper right quadrant and running counter-clockwise to 4 in the lower right quadrant. The subject was told that in the experimental slides neither the numbers nor the quadrant outlines would be present. He was to imagine the location of each quadrant and remember the numbering order. To make certain that the instructions were understood, several practice slides were presented and the subject asked to identify specified objects by reporting in which quadrant they were located. The examiner knew the true location and could readily determine whether the subject had understood the instructions or whether he needed additional instruction. When the subject had demonstrated that he understood the task, the actual test imagery was presented.

The 18 slides were presented in the same sequence to all of the experimental subjects. The mode of presentation varied from subject group to subject group, but the scenes were always presented in the same order. The steps followed by the examiner were:

- Inserted a slide into the viewer and set controls for brightness, intensity, and color in keeping with the chart settings prescribed for that slide.

- Checked visually to make certain that the slide was properly oriented and properly illuminated.

- Instructed the subject to begin his interpretation; when he began, started the timing device.

- The subject responded orally and the examiner recorded the number of objects (if more than one was reported for a named object), the identity of the object, and the quadrant location. The examiner made these entries on the answer sheet kept for that subject.

- When the subject had completed his information extraction for a slide, he told the examiner that he had nothing more to report. At this time, the examiner stopped the timer and recorded the total time required to interpret the slide.

The same procedure was repeated until all 18 slides had been interpreted. The subject had brief rest periods between successive slides since the examiner had to complete the set-up preparations for each new slide.

TARGET IDENTIFICATION ACCURACY

The column headings of Figure 2 are the independent variables. The row headings show the five dependent measures of the experiment. Row one shows that accuracy of target identification differed significantly among the scene sets. Although the 18 slides were grouped into three sets of six slides each to facilitate counterbalancing of the experimental tasks, the difference is of some interest. The number of targets in the three sets differed widely. Set A contained 57 targets, Set B about 68, and Set C about 157. Mean accuracy of target identification for the three scene sets was 64 percent for Set A, 79 percent for Set B, and 66 percent for Set C. It appears that the targets contained in Set B were easier for the average interpreter to identify than was the case for either Set A or Set C.

TARGET IDENTIFICATION COMPLETENESS

Row 2 of Figure 2 shows that the completeness of target identification differed significantly among the scene sets. Since Set C had the greatest number of targets, it might be expected that the completeness of target identification would be lowest for this set of slides. The results show that 42 percent of the targets in Set C were identified correctly, while 61 percent of Set B targets and about 51 percent of Set A targets were correctly identified. Here again, it appears that targets in Set B may have been easier to identify, since a larger percentage of the targets were correctly identified even though Set B contained more targets than Set A. The fact that completeness of target identification is lower for imagery containing a greater number of targets would be expected if a limited amount of time were allotted for the interpretation task. This was not the case in this experiment. The interpreter was to take the time needed to complete extraction of information from each slide and then notify the examiner that he was finished with the slide. Differences in the target numerosity among the three scene sets does not adequately explain the result.

The same result had been obtained in a previous study[5]. In that case, the experimental imagery was dichotomized on the basis of target density per exposure. Equal numbers of exposures containing three or fewer targets and four or more targets were used. Here, as in the present study, target identification completeness was significantly better for exposures containing three or fewer targets than for exposures containing four or more targets. This result was obtained even though the interpreters did not use all of the time allowed for completion of the experimental task. It might be hypothesized that the average interpreter reaches some number of target identifications in a given scene and then judges that the probability of there being additional targets present in that scene is so low as not to warrant additional search. This explanation is extremely tenuous and has not been substantiated by cross-validation experiments.

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[5] Beechler, R. L., S. H. Winterstein, R. M. Kamper, and T. E. Jeffrey. A study of rapid photo interpretation methods. Technical Research Report 1153. U. S. Army Behavioral Science Research Laboratory. June 1969.

TARGET DETECTION ACCURACY

Sole reliance upon measures of target identification might fail to demonstrate the advantage of recording ground scenes in chromatic color rather than achromatic color. Identification of a target depends upon specific signatures unique to that object in order for the interpreter to make the correct identification. Recognition of the more subtle cues might be accomplished with equal ease in either chromatic or achromatic color imagery. To insure that the possible advantage inherent in chromatic color imagery was not overlooked, two measures of target detection were analyzed. Target detection requires discrimination between the class of objects specified in the list of requirements and all other features in the imagery. This discrimination depends upon relatively gross features of the objects and does not require that the interpreter distinguish the presence of target signatures necessary for target identification. In the analysis of target detection accuracy, it was found that none of the independent variables produced a statistically significant difference in the performance of the subjects.

TARGET DETECTION COMPLETENESS

The completeness with which the interpreters made their target detections differed significantly among the three scene sets. Target detection was about 72 percent complete for targets in Set A, 67 percent complete for targets in Set B, and 57 percent complete for targets in Set C. Detection completeness was inversely related to the number of targets present in each set of slides. It was expected that subjects working for a limited period of time would tend to make nearly equal numbers of responses and thereby nearly equivalent numbers of correct detections. Under such a circumstance, the result obtained would be expected. However, this was not the case in this experiment. As described in the section for identification completeness, the interpreters set the time needed for completing the task. In the previous section a tentative hypothesis was advanced as a possible explanation for this result.

QUESTIONNAIRE RESPONSES

Although the results reported above were based on response data obtained from 12 interpreters, the questionnaire results are given for all 15 interpreters who took part in the experiment. The responses of these men to each item are shown below. A copy of the instructions used to administer the questionnaire along with a copy of the questionnaire itself is presented in Appendix B.

<u>Item 1.</u>	Yes	?	No
Do you think that by exaggerating a single color or combination of colors that you are able to detect greater detail than is possible when the scene is viewed in black and white?	10	1	4

Two thirds of the interpreters felt that color adds a useful dimension to reconnaissance imagery. This conviction was not supported by the accuracy and completeness of their target detections and identifications discussed previously.

Item 2.	Yes	?	No
Does the exaggeration of a single color or a combination of colors make possible the detection of details that would go unnoticed in a fixed color presentation such as Ektachrome?	1	2	12

Eight tenths of the respondents felt that variable control over the color presentation did not help them to pick out details that would be unnoticed in normal color presentation.

Item 3.

If your answer to Question 2 was YES, list the types of detail for which you think detection would be facilitated through the use of variable color.

Only one person answered Question 2 in the affirmative so that there can be no general consensus of opinion for Item 3. This one interpreter stated: "An exaggeration of Blue & White or Red & White make a sharper contrast of shadow with also a greater color difference of surroundings."

It is quite possible that interpreters avoided the YES response in Item 2 because they felt unable to give specific examples required by Question 3. They may have had a generalized feeling that differential control of color mixture and/or light intensity had some value in bringing out detail but were unable to verbalise the feeling. The questionnaire seems to be faulty in this respect.

Item 4.	Yes	?	No
Do you like this type of binocular viewer?	7	0	8

The group was about evenly divided in their feelings for this device. Reasons for disliking the viewer include the lack of stereo capability and the fact that the viewer is difficult to use if one wears glasses. This latter objection is not insurmountable since a rear projection device that will display TOC imagery is in existence.

Item 5.	Yes	?	No
Does this variable color device make it possible to obtain a faithful reproduction of the colors in the actual scene?	4	2	9

The interpreters' knowledge concerning the scene colors had to come from viewing the Ektachrome slide showing the scene. Therefore, the actual impact of the question is that the man is being asked to compare the degree to which TOC imagery approximates normal color imagery. The results indicate that six tenths of the interpreters judged that TOC does not look the same as Ektachrome imagery.

Item 6.	Yes	?	No
Would you recommend that variable color capability be adopted for operational image interpretation?	4	2	9

The frequency distribution for Item 5 and Item 6 are identical. In fact, a comparison of the responses to the two items shows that eight out of nine of the NO responses were made by the same interpreters with three out of four of the YES responses being made by the same men. The men taking part in this experiment may have had too little exposure to the TOC system to have an informed opinion. However, only about 25 percent of them felt that this system holds promise for image interpretation.

Item 7.

List the advantages and disadvantages that you see in using color film for reconnaissance purposes in general and with the use of this technique for variable color in particular.

The purpose of this item was to elicit some thoughts from the interpreters concerning the strengths and weaknesses they perceived in the two competing systems for color and for black-and-white as the common denominator. In distilling these comments, those which appeared to tap the same thought have been placed under a single listing. Comments that referred to the viewing device have been listed under Item 4 since they are more appropriate to that item.

	Advantages	Disadvantages
Color	1. Gives a scene a "natural" appearance	1. High cost
	2. Increases detection of objects by enhancing shape detail	2. Relatively long processing time required
	3. Less monotonous to work with	
	4. Less eye strain in working with color imagery	
TOC	1. Provides some color	1. Has poor image resolution
	2. Preferable to black-and-white	2. Poor color rendition

In summary, the interpreters appeared to feel that color is a useful characteristic of imagery for image interpretation but more costly in

APPENDIX A SCORE MATRICES

Ground truth data are available for the targets present at the various target sites of the UNDERBRUSH Range. This source of information combined with actual verification that such targets were present in the selected set of 18 slides was used to establish the target content of the experimental imagery. Verification of the documented lists of target content was judged necessary to make certain that poorly imaged targets or targets concealed by vegetation were not included as targets the subjects of this experiment were expected to report. In addition to the foregoing reason, some of the slides used contained scenes for which no ground truth was available. From these sources of basic information, the list of targets contained in the imagery and the slide quadrants in which they were located were determined. This procedure provided the scoring key against which the responses of the experimental subjects were compared.

The responses of each subject were checked against the scoring key and the number of correct identifications, misidentifications, omissions, inventions, and time required for interpretation was determined for each slide. After these results were checked, the four derived measures of performance were determined for each slide for every subject. For each measure of performance, the total score over the six slides presented under the same mode of presentation--Ektachrome, black-and-white, or Total Optical Color (TOC)--was determined for each subject. The five tables that follow give these scores for the twelve subjects. These score matrices show the simple sum of the ratio scores over the six slides. Averages could have been computed but since this step would not affect the significance test of differences, this step was omitted.

Table A-1

IDENTIFICATION ACCURACY SCORE MATRIX

Interpreter Code Number	Group Code	Scene Set and Presentation Color: Scene Set	Ek	Scene Set	B&W	Scene Set	TOC	SUM
1	I	A	3.80	C	4.36	B	4.69	12.85
2	I	A	3.68	C	3.42	B	4.45	11.55
3	I	A	3.33	C	3.12	B	4.06	10.51
4	I	A	3.83	C	4.48	B	4.74	13.05
SUM			14.64		15.38		17.94	47.96
5	II	C	4.37	B	5.57	A	3.65	13.59
6	II	C	4.22	B	4.88	A	4.50	13.60
7	II	C	3.58	B	3.44	A	2.65	9.67
8	II	C	5.44	B	4.64	A	5.00	15.08
SUM			17.61		18.53		15.80	51.94
9	III	B	5.93	A	4.28	C	3.59	13.80
10	III	B	4.90	A	2.99	C	2.97	10.86
11	III	B	4.29	A	3.92	C	3.59	11.80
12	III	B	5.39	A	4.52	C	4.39	14.30
SUM			20.51		15.71		14.54	50.76
COLUMN SUMS			52.76		49.62		48.28	150.66
SET SUMS		A	46.15	B	56.98	C	47.53	

Table A-2

ANALYSIS OF VARIANCE SUMMARY OF TARGET IDENTIFICATION ACCURACY SCORES

Source of Variation		Sum of Squares	df	Mean Square	F
Between:	Groups	.6964666	2	.3482	.332
	(P w G) = e_1	9.4449667	9	1.0494	-----
Within:	Scene Sets	5.79155	2	2.8957	14.692**
	Color Mode	.8812666	2	.4406	2.236
	Latin Square Residual	.7952168	2	.3976	2.017
	S x (P w G) = e_2	3.5476333	18	.19709	-----
	TOTAL	21.1571	35		

** Means significantly different, $P \leq .01$.

Table A-3

IDENTIFICATION COMPLETENESS SCORE MATRIX

Interpreter Code Number	Group Code	Scene Set and Presentation Color						SUM
		Scene Set	Ek	Scene Set	B&W	Scene Set	TOC	
1	I	A	3.39	C	3.13	B	3.52	10.04
2	I	A	3.08	C	1.79	B	3.36	8.23
3	I	A	3.20	C	2.58	B	4.10	9.88
4	I	A	2.00	C	2.48	B	3.07	7.55
SUM			11.67		9.98		14.05	35.70
5	II	C	2.77	B	4.24	A	3.20	10.21
6	II	C	3.10	B	4.11	A	3.34	10.55
7	II	C	1.92	B	2.55	A	2.30	6.77
8	II	C	3.60	B	3.22	A	2.92	9.74
SUM			11.39		14.12		11.76	37.27
9	III	B	4.44	A	3.46	C	2.26	10.16
10	III	B	3.93	A	3.00	C	1.84	8.77
11	III	B	3.40	A	3.12	C	1.80	8.32
12	III	B	4.29	A	3.93	C	2.91	11.13
SUM			16.06		13.51		8.81	38.38
COLUMN SUMS			39.12		37.61		34.62	111.35
SET SUMS		A	36.94	B	44.23	C	30.18	

Table A-4

ANALYSIS OF VARIANCE SUMMARY OF TARGET IDENTIFICATION COMPLETENESS SCORES

Source of Variation		Sum of Squares	df	Mean Square	F
Between:	Groups	.3022055	2	.1511	.221
	(P w G) = e_1	6.164825	9	.68498	-----
Within:	Scene Sets	8.2290055	2	4.11450	29.995**
	Color Mode	.8741722	2	.4370861	3.186
	Latin Square Residual	.8468057	2	.4234028	3.087
	S x (P w G) = e_2	2.46915	18	.137175	-----
	TOTAL	18.8861639	35		

** Means significantly different, $P \leq .01$.

Table A-5

DETECTION ACCURACY SCORE MATRIX

Interpreter Code Number	Group Code	Scene Set and Presentation Color: Scene Set	Ek	Scene Set	B&W	Scene Set	TOC	SUM
1	I	A	4.93	C	5.98	B	4.82	15.73
2	I	A	5.17	C	4.71	B	4.63	14.51
3	I	A	3.50	C	4.43	B	5.48	13.41
4	I	A	5.00	C	4.90	B	5.00	14.90
SUM			18.60		20.02		19.93	58.55
5	II	C	5.00	B	5.80	A	5.20	16.00
6	II	C	4.98	B	5.88	A	5.67	16.53
7	II	C	4.93	B	4.86	A	5.50	15.29
8	II	C	5.89	B	4.76	A	5.00	15.65
SUM			20.80		21.30		21.37	63.47
9	III	B	5.93	A	6.00	C	5.87	17.80
10	III	B	5.93	A	5.10	C	5.66	16.69
11	III	B	4.32	A	5.35	C	4.84	14.51
12	III	B	6.00	A	5.69	C	6.00	17.69
SUM			22.18		22.14		22.37	66.69
COLUMN SUMS			61.58		63.46		63.67	188.71
SET SUMS		A	62.11	B	63.41	C	63.19	

Table A-6

ANALYSIS OF VARIANCE SUMMARY OF TARGET DETECTION ACCURACY SCORES

Source of Variation		Sum of Squares	df	Mean Square	F
Between:	Groups	2.8009555	2	1.40047775	3.565
	(P w G) = e_1	3.5353417	9	.392815744	-----
Within:	Scene Sets	.0806889	2	.04034	.137
	Color Mode	.2207389	2	.11037	.375
	Latin Square Residual	.0705556	2	.03528	.120
	S x (P w G) = e_2	5.2940833	18	.29412	-----
	TOTAL	12.0023639	35		

Table A-7

DETECTION COMPLETENESS SCORE MATRIX

Interpreter Code Number	Group Code	Scene Set and Presentation Color: Scene Set	Ek	Scene Set	B&W	Scene Set	TOC	SUM
1	I	A	4.90	C	4.39	B	3.66	12.95
2	I	A	4.48	C	2.63	B	3.57	10.68
3	I	A	3.35	C	3.76	B	4.97	12.08
4	I	A	3.15	C	2.64	B	3.30	9.09
SUM			15.88		13.42		15.50	44.80
5	II	C	3.32	B	4.40	A	4.44	12.16
6	II	C	3.74	B	5.11	A	4.49	13.34
7	II	C	2.39	B	3.37	A	4.37	10.13
8	II	C	4.02	B	3.31	A	2.92	10.25
SUM			13.47		16.19		16.22	45.88
9	III	B	4.44	A	5.14	C	3.96	13.54
10	III	B	4.43	A	4.95	C	4.05	13.43
11	III	B	3.46	A	4.30	C	2.26	10.02
12	III	B	4.51	A	5.08	C	4.13	13.72
SUM			16.84		19.47		14.40	50.71
COLUMN SUMS			46.19		49.08		46.12	141.39
SET SUMS		A	51.57	B	48.53	C	41.29	

Table A-8

ANALYSIS OF VARIANCE SUMMARY OF TARGET DETECTION COMPLETENESS SCORES

Source of Variation		Sum of Squares	df	Mean Square	F
Between:	Groups	1.650650	2	.8253	.882
	(P w G) = e_1	8.425225	9	.9361	-----
Within:	Scene Sets	4.6482666	2	2.3241	6.142**
	Color Mode	.4755166	2	.2378	.628
	Latin Square Residual	.2145168	2	.1073	.283
	S x (P w G) = e_2	6.8115	18	.3784	-----
	TOTAL	22.225675	35		

** Means significantly different, $P \leq .01$.

Table A-9

TOTAL TIME (IN SECONDS) SCORE MATRIX

Interpreter Code Number	Group Code	Scene Set and Presentation Color: Scene Set	Ek	Scene Set	B&W	Scene Set	TOC	SUM
1	I	A	615	C	1045	B	616	2276
2	I	A	469	C	1114	B	656	2239
3	I	A	868	C	1212	B	768	2848
4	I	A	339	C	563	B	330	1232
SUM			2291		3934		2370	8595
5	II	C	737	B	685	A	467	1889
6	II	C	518	B	500	A	273	1291
7	II	C	493	B	500	A	390	1383
8	II	C	659	B	365	A	370	1394
SUM			2407		2050		1500	5957
9	III	B	283	A	363	C	614	1260
10	III	B	422	A	460	C	572	1454
11	III	B	417	A	324	C	469	1210
12	III	B	605	A	532	C	751	1888
SUM			1727		1679		2406	5812
COLUMN SUMS			6425		7663		6276	20364
SET SUMS		A	5470	B	6147	C	8747	

Table A-10

ANALYSIS OF VARIANCE SUMMARY OF TOTAL TIME SCORES (SECONDS)

Source of Variation		Sum of Squares	df	Mean Square	F
Between:	Groups	409,032.16	2	204,516.08	2.971
	(P w G) = e_1	619,569.17	9	68,841.02	-----
Within:	Scene Sets	498,807.16	2	249,403.58	37.324**
	Color Mode	96,628.16	2	48,314.08	7.230**
	Latin Square	20,919.52	2	10,459.76	1.565
	Residual S x (P w G) = e_2	120,277.83	18	6,682.10	-----
	TOTAL	1,765,234.00	35		

** Means significantly different, $P \leq .01$.

APPENDIX B ANCILLARY MATERIALS DISTRIBUTED TO SUBJECTS

INSTRUCTIONS TO SUBJECTS

TARGET LIST

PREFERENCE QUESTIONNAIRE

INSTRUCTIONS TO SUBJECTS

THE TASK YOU ARE TO PERFORM INVOLVES IDENTIFYING VARIOUS TACTICAL OBJECTS AND/OR ACTIVITIES THAT ARE IMAGED ON A SET OF PHOTOGRAPHIC SLIDES THAT YOU WILL BE SHOWN.

FIRST, WE WILL ADJUST THE BINOCULAR VIEWER TO ADAPT IT TO YOUR PERSONAL CHARACTERISTICS. Set interoptic distance to 64mm, brightness and white controls to maximum value, and the red, blue, and green controls to zero. Insert the first slide and verify that it is properly oriented.

LOOK INTO THE VIEWER. YOU WILL SEE FOUR NUMBERS ON A GRIDDED FIELD. TURN THIS KNOB (point to focus control) UNTIL YOU GET THE SHARPEST IMAGE POSSIBLE TO YOUR RIGHT EYE. NOW, TURN THIS KNURLED RING ON THE LEFT HAND OPTIC UNTIL YOU OBTAIN THE SHARPEST FOCUS POSSIBLE TO YOUR LEFT EYE. IF THE TWO IMAGES DO NOT FUSE INTO A SINGLE IMAGE, ADJUST THE INTEROPTIC DISTANCE BY MOVING THE EYEPIECES TOGETHER OR APART UNTIL A SINGLE IMAGE IS OBTAINED.

NOTICE THAT THE VISUAL FIELD IS DIVIDED INTO FOUR SECTIONS NUMBERED ONE THROUGH FOUR IN A COUNTERCLOCKWISE DIRECTION STARTING IN THE UPPER RIGHT CORNER. IN VIEWING THE LATER SLIDES, YOU ARE TO MENTALLY DIVIDE THE VIEWING AREA IN THE SAME WAY. USE THIS NUMBERING SYSTEM IN MAKING REFERENCE TO AN AREA OF THE SLIDE. DO YOU UNDERSTAND THE AREA DESIGNATION SYSTEM I HAVE JUST DESCRIBED? Answer any questions and then insert the slide of the color charts, set the controls as required and verify slide orientation.

THIS SLIDE SHOWS A VARIETY OF RESOLUTION CHARTS AND COLOR CHARTS. TELL ME THE NUMBER OF THE AREA IN WHICH THE FOLLOWING OBJECTS APPEAR: THE LARGE GREEN COLOR PATCH? (area 1), THE STATION WAGON? (area 2), THE BROWN PATCHES? (area 3), Review coding system if necessary. THE NEXT SLIDE IS BLACK-AND-WHITE. IN WHICH AREA DOES THE BARGE CARRYING A CRANE APPEAR? (area 2). THIS COMPLETES THE PRELIMINARY INSTRUCTIONS.

IN THE TEST YOU ARE TO REPORT ONLY THOSE TARGETS THAT ARE SHOWN ON THIS TARGET LIST. Present the target list to the subjects and give them as much time as needed to become familiar with it. YOU ARE TO IDENTIFY AND LOCATE BY AREA NUMBER THE TARGETS YOU DETECT AND IDENTIFY ON THE FOLLOWING ASSORTMENT OF COLOR AND BLACK-AND-WHITE SLIDES.

A TIMER WILL BE ACTIVATED AS EACH NEW SLIDE IS PRESENTED. WE WILL BE RECORDING YOUR RESPONSES AND THE TIME REQUIRED TO MAKE THEM THROUGHOUT THE TEST. THE CLICKING NOISE YOU WILL HEAR IS THE COUNTER WE ARE USING TO DETERMINE TIME.

I WILL INSERT EACH SLIDE, ADJUST THE CONTROLS, RESET THE TIMER AND THEN GIVE YOU THE SIGNAL TO BEGIN SEARCHING FOR AND REPORTING TARGETS. USE THE FOLLOWING ORDER IN MAKING YOUR REPORTS: FIRST, STATE THE NUMBER OF TARGETS; SECOND, THE SPECIFIC TYPE OF TARGET; LAST, THE NUMBER OF THE AREA IN WHICH THE TARGET IS LOCATED. AN EXAMPLE OF SUCH A RESPONSE MIGHT BE: "THREE, 3/4-TON TRUCKS IN AREA NUMBER TWO."

WHEN YOU COMPLETE YOUR SEARCH OF EACH SLIDE, TELL ME THAT YOU HAVE NOTHING MORE TO REPORT. THIS WILL ENABLE ME TO KNOW WHEN TO READ YOUR COMPLETION TIME FOR THAT SLIDE.

ARE THERE ANY QUESTIONS?

TARGET LIST

TRANSPORT	EMPLACEMENTS AND STRUCTURES	WEAPONS	MISCELLANEOUS
5-ton Truck	Revetment	Missile	Railroad Ties
$2\frac{1}{2}$-ton Truck	AA Position	Rocket	55 gallon Drums
3/4-ton Truck	Foxhole	Drone	Site Marker
$\frac{1}{4}$-ton Truck	Fireplace	AA Gun	Tarpaulin
Civilian Vehicle	Tower, Observation	SP Gun	Assault Strip
Van	Hut	Launcher, Missile	Bomb Crater
Sampan	Shed, Metal	Launcher, Rocket	Ship Hulk
Tanks	Building		Antenna, Radar
APCs	Hangar		Generator/Compressor
Ship	Pumping Station		
	Floating Drydock		
	Crane, Traveling		
	POL Storage Tanks		

2	1
3	4

AREA DESIGNATOR CODE

QUESTIONNAIRE INSTRUCTIONS

IN THE SET OF SLIDES THAT YOU HAVE JUST COMPLETED, COLORED SCENES WERE PRODUCED BY TWO DIFFERENT METHODS. IN ONE CASE A CONVENTIONAL COLOR TRANSPARENCY WAS USED--FOR THIS EXPERIMENT EKTACHROME COLOR TRANSPARENCIES WERE USED. THE SECOND METHOD USED BLACK-AND-WHITE TRANSPARENCIES ON WHICH COLOR INFORMATION HAD BEEN CODED WHEN THE FILM WAS EXPOSED. THE BINOCULAR VIEWER MAKES IT POSSIBLE TO REPRODUCE THE COLORED SCENE FROM THE BLACK-AND-WHITE TRANSPARENCY. THE FOLLOWING CODE WILL BE USED TO REFER TO THE THREE TYPES OF DISPLAY:

COLOR - REFERS TO THE NORMAL THREE-COLOR PROCESS
B&W - REFERS TO SLIDES DISPLAYED IN BLACK-AND-WHITE
TOC - REFERS TO COLOR PRODUCED FROM BLACK-AND-WHITE

IN THE PRECEDING PORTION OF THE EXPERIMENT ALL CONTROLS WERE MANIPULATED BY THE EXPERIMENTER. IN THIS PART OF THE EXPERIMENT, YOU WILL ADJUST THE CONTROLS. BEFORE YOU START TO VIEW THE SLIDES, LOOK AT THE SET OF QUESTIONS WE WANT YOU TO ANSWER AFTER YOU COMPLETE THE REVIEW OF THE SLIDES. KEEP THESE QUESTIONS IN MIND AS YOU ARE LOOKING AT THE SLIDES.

BEFORE INSERTING A BLACK-AND-WHITE SLIDE, SET THE BLUE, RED AND GREEN CONTROLS TO ZERO. SET BRIGHTNESS AND WHITE TO $8\frac{1}{2}$. STUDY THE SLIDE FOR A WHILE IN THIS B&W MODE. THEN BEGIN TO CHANGE THE COLOR BY MANIPULATING THE COLOR CONTROLS.

TRY TO DISREGARD THE FACT THAT THE SCENE IS AESTHETICALLY MORE "PLEASANT" TO LOOK AT IN COLOR AND TRY TO CONCENTRATE ON DECIDING IF TOC OFFERS ADVANTAGES AS FAR AS INTELLIGENCE INFORMATION AND INTERPRETABILITY ARE CONCERNED.

CHANGE TO THE NEXT SLIDE WHICH SHOWS THE SAME SCENE IN <u>COLOR</u>. SET THE RED, BLUE, AND GREEN CONTROLS TO ZERO AND BRIGHTNESS AND WHITE TO $8\frac{1}{2}$ AS INSTRUCTED PREVIOUSLY. STUDY THIS DISPLAY AND COMPARE IT MENTALLY WITH THE TOC DISPLAY YOU VIEWED OF THIS SAME SCENE.

FOLLOW THE SAME PROCEDURE AS THAT OUTLINED IN THE PREVIOUS TWO STEPS FOR THE NEXT PAIR OF SLIDES. WHEN YOU HAVE COMPLETED THE NEXT PAIR OF SLIDES, ANSWER THE QUESTIONS GIVEN IN THE QUESTIONNAIRE. WRITE DIRECTLY ON THE QUESTIONNAIRE. THERE IS NO TIME LIMIT.

PREFERENCE QUESTIONNAIRE

The purpose of this questionnaire is to obtain information concerning your impressions about the usefulness of the viewing device employed in this experiment.

Answer the questions by circling the letter or symbol that represents your response--Y for YES, ? for UNDECIDED, and N for NO. For the open-ended items, write your response in the space provided. If additional space is needed use blank sheets. Number items for which response applies.

1. Do you think that by exaggerating a single color or combination of colors that you are able to detect greater detail than is possible when the scene is viewed in black and white? . . . . Y ? N

2. Does the exaggeration of a single color or a combination of colors make possible the detection of details that would go unnoticed in a fixed color presentation such as ektachrome? . . . . Y ? N

3. If your answer to Question 2 was YES, list the types of detail for which you think detection would be facilitated through the use of variable color.

   ____

   ____

   ____

4. Do you like this type of binocular viewer? . . . Y ? N

5. Does this variable color device make it possible to obtain a faithful reproduction of the colors in the actual scene? . . . . Y ? N

6. Would you recommend that variable color capability be adopted for operational image interpretation? . Y ? N

7. List the advantages and disadvantages that you see in using color film for reconnaissance purposes in general and with the use of this technique for variable color in particular.

   ____

   ____

   ____